FOLDABLE FRAME-SUPPORTED THIN-MEMBRANE ARRAY

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Introduction: For Earth remote sensing applications, a synthetic aperture radar (SAR) typically employs an antenna with fairly long along-track aperture in order to achieve the required resolution, swath width, and data rate. 10m-long antennas, such as those for SeaSat [1] and SIR-A,B,C [2] series, have been flown previously. To maintain an acceptable electrical flatness across this long aperture, very massive antenna support and deployment structures have been used to date. For example, the fixed-beam L-band SeaSat antenna, which used a microstrip array with a honeycomb substrate and 10m x 3m aperture, had a mass of 250 kg (including deployment mechanism). The beam-scanning L/C/X-band shuttle-based SIR-C antenna had a mass of 1800 kg. These massive antenna systems generally require a launch vehicle with large stowage volume and heavy-payload-lift capability. To achieve high launch volume efficiency and to reduce payload weight, a new antenna concept [3] has recently been developed. This concept uses multiple foldable low-mass rigid frames to support the double-layer thin-membrane radiating apertures. The frames are deployed by using the novel "carpenter tape" hinge, which is a simple, low cost, low mass, and reliable deployment and latching mechanism. With the foldable thin-membrane array concept presented here, it is believed that future Earth remote sensing SAR antennas can achieve a mass goal of less than 100 kg in the 10m x 3m aperture class.

Antenna description: The complete array antenna would consist of 14 foldable panels that are made deployable by using the carpenter-tape hinges. Prior to deployment, these panels could be folded up to form a relatively small stowed volume of 2.85m x 0.7m x 0.9m. In this development effort, instead of the full-size array, only a half array with 7 panels were fabricated and tested. This half array, shown in a photo in Figure 1, has a total radiating aperture of 5m x 2.85m. Each panel of this half array, sketched in Figure 2, is a rectangular rigid frame that supports a two-layer, thin-membrane, L-band subarray aperture. The rigid frame is made of very low-mass graphite composite material with honeycomb core and graphite epoxy face sheets. In each framed aperture, it has an aperture size of 2.85m x 0.71m and 14 rows of microstrip patch radiators with each row consisting of two 1x2 series-fed dual-polarized subarrays. The spacing between any two adjacent rows is 0.8 free-space-wavelength at the center operating frequency of 1.25 GHz. The spacing between adjacent patches in the horizontal direction is 0.74 free-space-wavelength. Each 1x2 subarray, as shown in Figure 2, can be connected to T/R modules that may be rigidly mounted onto the frame. The chief advantage of this "frame" concept is that each frame is able to rigidly support an appropriate number of T/R modules and phase shifters for achieving the desired beam scan. With this particular design, the complete array is able to scan its beam to ±20° in the vertical direction and a few degrees in the horizontal direction. In this development, however, T/R modules and phase shifters were not used and all the 1x2 subarrays were connected together behind the ground plane via coax cables and discrete power dividers. For the two-layer thin-membrane structure, as shown in the photo in Figure 3, the top layer has all the radiating patches and microstrip transmission lines, while the bottom layer serves as the ground plane. Both layers are made of 5-micron-thick copper deposited on 0.05mm-thick Kapton membrane. The two layers are separated 1.3cm apart for the purpose of achieving the required 80 MHz RF bandwidth.

To deploy the foldable panels, the novel but simple "carpenter tape" hinges were used. Figure 4 shows the carpenter tape hinge in its deployed and folded positions. Each hinge is comprised of two tape stacks with their concave side facing inward. Each of the stacks may have one to four layers of tapes. The tape hinge has two distinct performance regimes: When folded, they exhibit non-linear behavior, with the ability to store significant amounts of energy in the tape deformation, which is released upon deployment. When latched after deployment, it acts as a rather stiff composite beam (linear behavior) to support the panels.

Performance results: The half-size (5m x 2.85m) breadboard array antenna, shown in Figure 1, was measured for its radiation characteristics at an outdoor far-field range. The typical measured patterns at 1.25 GHz for the vertically polarized array in both the E and H-plane cuts are shown in Figures 5 and 6, respectively. The peak sidelobe is about –12 dB, which is close to that expected for a uniformly distributed array. The cross-pol lobes are mostly below –20 dB in the H-plane pattern, but are showing –15 dB level in the E-plane. For SAR application, reduction of this –15 dB cross-pol radiation to –20 dB level is needed in future development of this array. The measured 3 dB beamwidths in the E-plane and H-plane directions are 4.47° and 2.44°, respectively, which are very close to those expected for a uniformly distributed aperture of 2.85m x 5m. The input return losses measured at the inputs of the 1x2 subarray are below the required –10 dB level over a bandwidth of ±40 MHz centered at 1.25 GHz. The measure array efficiency (not including the losses of the coax cables and discrete power dividers) is 85%, which is considered quite good.

Acknowledgment: The research described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

References:

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3. J. Huang, M. Lou, and E. Caro, "Super-low-mass spaceborne SAR array concepts," IEEE AP-S symposium, pp. 1288-1291, July 1997.

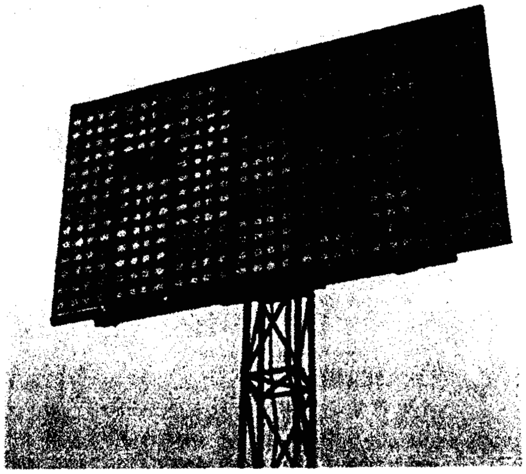

Figure 1. Photo of the half-size array with 7 panels

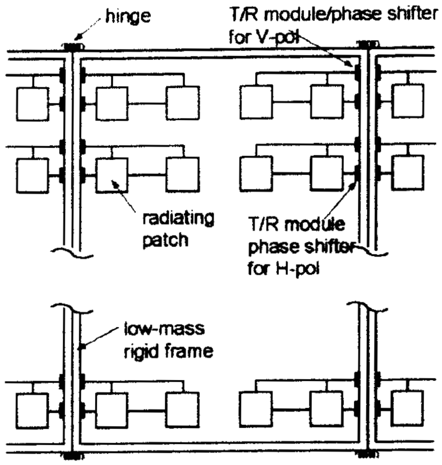

Figure 2. Sketch of each panel's major components

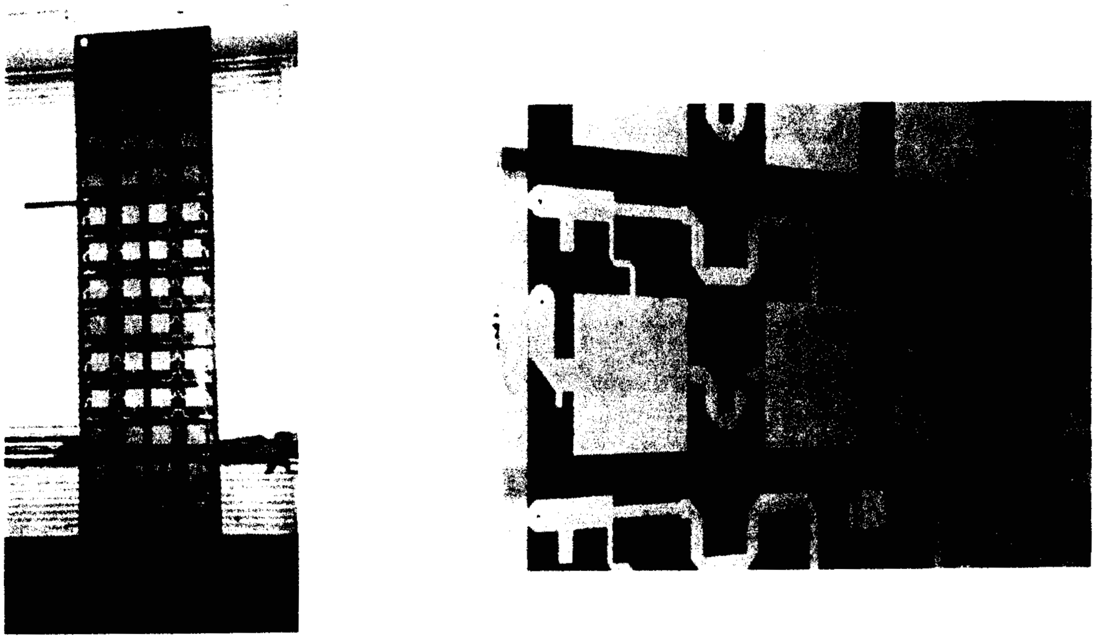

Figure 3. Photo of a single panel and a close-up view of the two-layer membranes

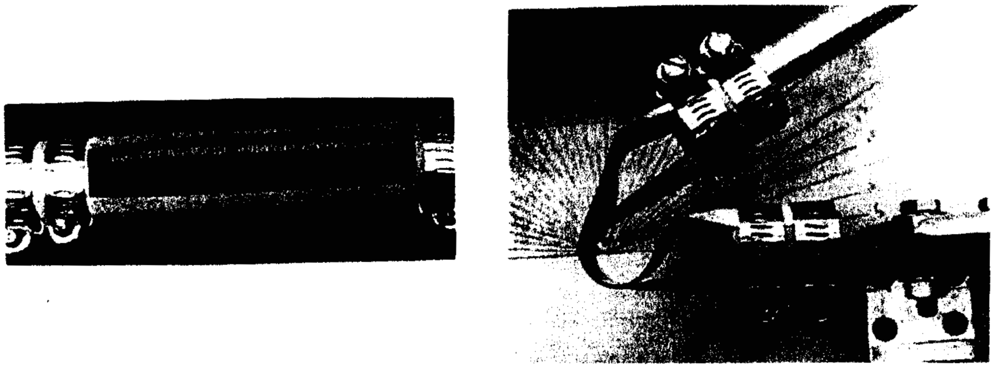

Figure 4. The "carpenter tape" hinge

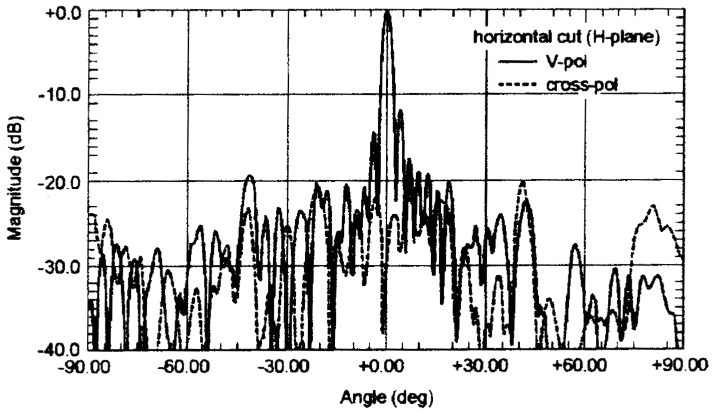

Figure 5. Pattern measured for the vertical polarization port in the horizontal cut of Figure 1

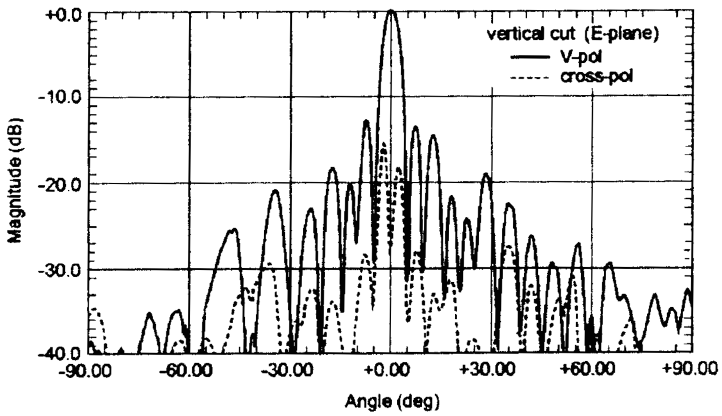

Figure 6. Pattern measured for the vertical polarization port in the vertical cut of Figure 1